Coastal Benthic Optical Properties of Coral Environments: ROV/AUV Imaging

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LONG-TERM GOALS

The deconvolution, quantification, and interpretation of the various components of water-leaving radiance in shallow coastal waters with emphasis on coral environments is the long term goal of the project. This project is a follow on to Award Number N00014-95-1-0578 (see accompanying report).

OBJECTIVES

In this project, objectives include the development of instrumentation and models to measure and predict the contribution of bottom reflectance to upwelling radiance in coastal waters. An underlying objective, then, is the development of the methodologies required to remotely classify bottom types in varying water depths. Intrinsic in this effort is the need to address the inherent problems of scale between *in situ* and remotely sensed data and to perform rigorous data calibration/validation while working toward optical closure.

APPROACH

In the previous funding year of the project, transects over coral bottoms were laid out and mapped by divers and by the Fluorescence Imaging Laser Line Scanner (FILLS). Instrumentation aboard the Remotely Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV) platforms were used to determine the color and intensity of bottom elements from different altitudes. The goal was to correct imagery for path radiance and attenuation, providing bottom albedo estimates for the dominant bottom types/features, to image bottom fluorescence, and to measure the vertical spectral structure of the upwelling and downwelling light fields. The analyses required rigorous validation/calibration efforts and modelling efforts. Simultaneously, effort was expended toward developing simple, relatively low-cost methods which could exploit gross bottom reflectance signatures to yield useful data. Finally, the ultimate utility of the effort required the incorporation of a precision geodetic positioning system and compatible methodologies.

WORK COMPLETED

Work during this period has consisted of reduction and modelling of CoBOP'96 and TWIST2

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data as well as preparation for 1998 CoBOP field excercizes in the Bahamas.

- Significant effort has been expended toward building a JAVA-based, data archive site for the CoBOP project team for interactive data exploration on the word wide web.
- A rigorous check of the geometric collection performance (cosine response) of USF-developed, 512-channel in situ irradiometers and of a LICOR-1800 has been performed (English et. al. 1998).
- Methods have been presented to estimate scattering by large (>0.1 mm) particles (Hou et. al. 1997) and a forward-angle scattering correction for transmissometers determined by the large-particle size distribution (Hou et. al. 1998).
- A method has been described which utilized color video taken from the OV-II AUV to calculate the percent live sea-bottom cover (Renadette et. al. 1997, 1998).
- A method has been developed to model and utilize downwelling irradiance spectra affected by wave focusing (Costello et. al. 1997).
- A method to quantify the absorption by phytoplankton for subtropical waters has been published (Bissett et al. 1997).
- A method to predictively model the optical properties of the Sargasso Sea through a primary production model has been submitted (Bissett et al. submitted).

RESULTS

- Water-Raman scattering and chlorophll a fluorescence are extremely significant components of the upwelling light field at depths > 2 m and wavelengths > 520 nm over coraline environments and cannot be ignored in evaluating bottom-reflected (actively or passively) radiance (Fig. 1).
- Solar-stimulated fluorescence at 685 nm from sediments due to benthic diatoms is ubiquitous on the Florida shelf and is apparent in bottom imagery from depths of 7 m to > 20 m but < 30 m during the summer.
- Animals (e.g. sponges) and man-made objects are readily apparent by their dark contrast with the bright, red, bottom fluorescence from benthic diatoms, coral symbionts, and macrophytes.
- Range to various components in an image greatly effects the 685 fluorescence signal since the e-folding depth through water is 2.5 m. Correction for range is critical for image interpretation (see Carder and Costello: N00014-96-1-5013
- Wave focusing has a very significant spectral impacton the instantaneous downwelling light field on clear days providing red-rich irradiance in focal zones and blue-rich irradiance in divergence zones (Fig. 2). Coral and vegetation fluorescence are spectrally and temporally dependent on the incident light field, and fluorescence “spill-over” may occur when photosynthetic reaction centers are full during wave focusing events but not for steady-state conditions providing the same time-averaged photon quality and quantity. Field measurements of IOPs and AOPs have allowed spectral model closure calculations to simulate the instantaneous spectral light field measurements. Increases in aerosols decrease these fluctuations due to wave focusing, stabilizing the light field (Costello et al. 1997).

IMPACT/APPLICATIONS

In our analysis of our hyperspectal light profile datasets, it soon became apparent that wave focusing and Raman scattering introduced significant complexity to models of the submarine light field. Moreover, modelling efforts toward addressing the complexities using Smith and Baker’s (1981) water

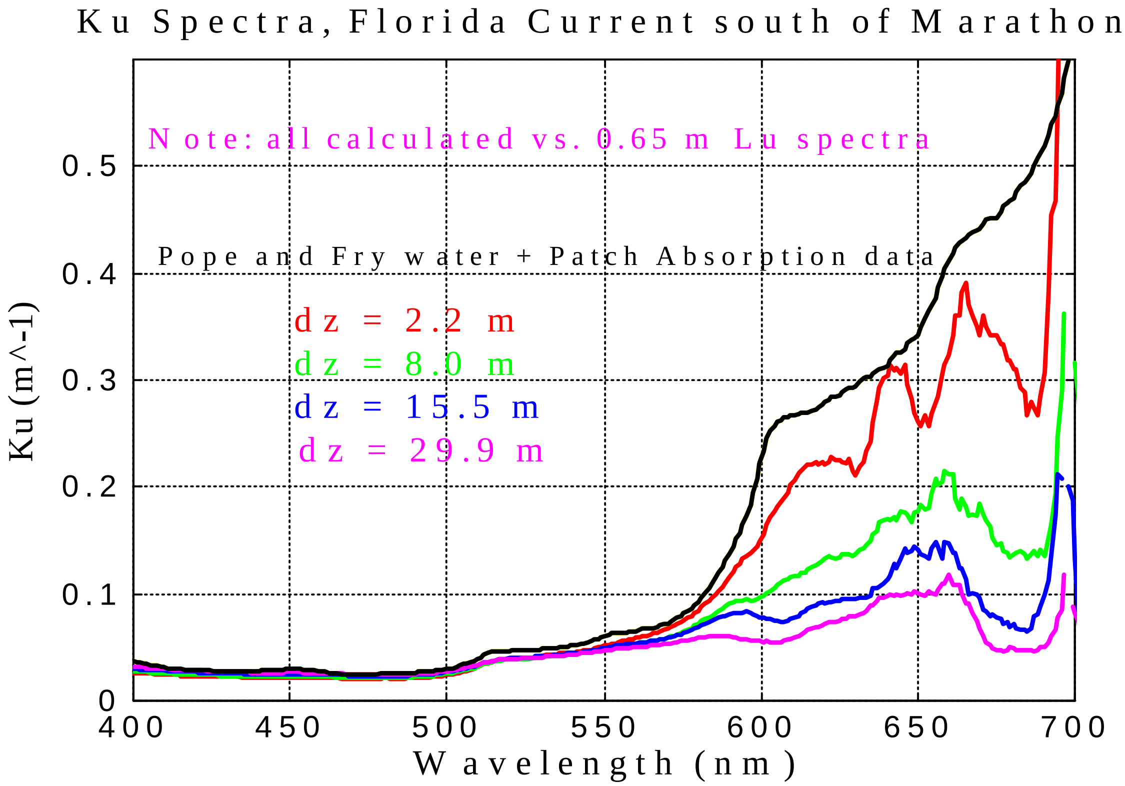

Figure 1. Ku spectra showing the effects of Raman scattering > 520 nm and chlorophyll a fluorescence at 685 nm. See text for discussion.

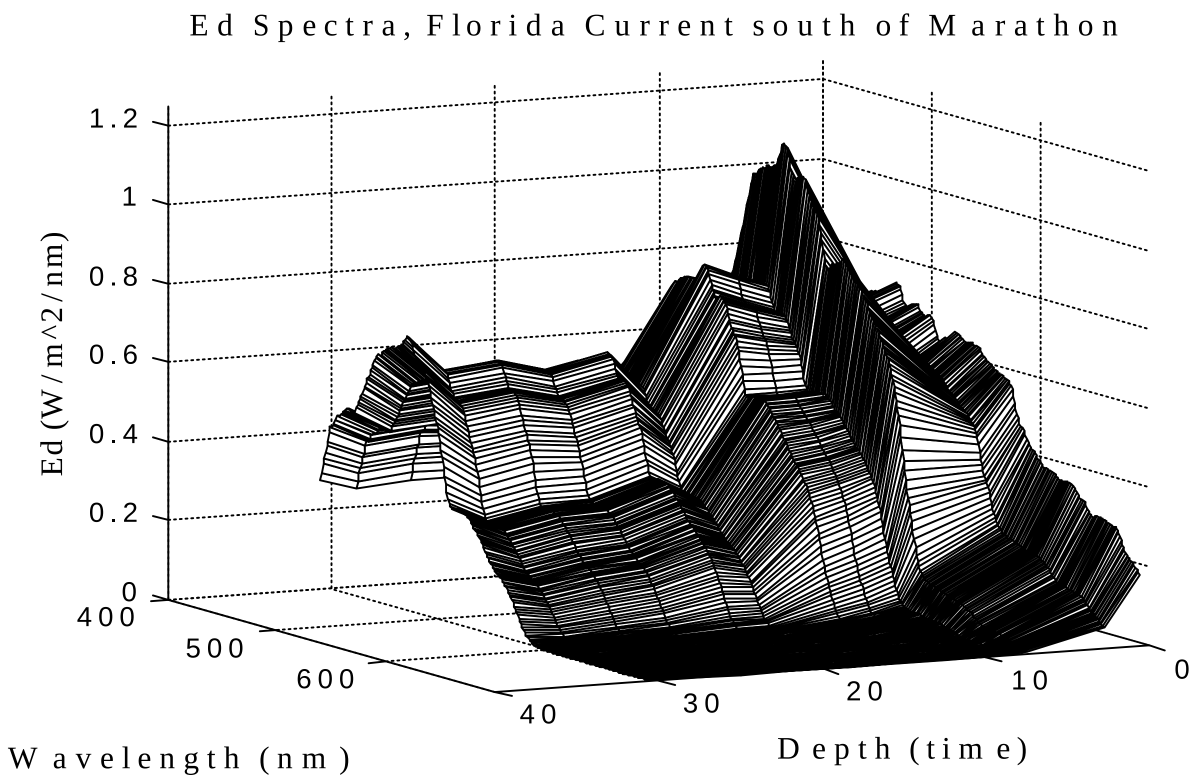

Figure 2. Ed spectra acquired in the presence of wave focusing. Note significant effects even at red wavelengths in the 9 m sample and overall effects as deep as 30 m. See text for discussion.

absorption numbers were generally fruitless. Use of Pope and Fry (1997) numbers, modelled skylight and sunlight fields (Gregg and Carder, 1990) and focus/defocus of the sunlight contribution provided modelled light fields consistent with measurements. Fluorescence and primary production models need to consider the nonlinear aspects of this light field versus traditional time-averaged methods.

The differences in the 685 nm fluorescence yields, suggested by our observations, ranged from high for hard-bodied coral, medium for branching coral, to low for benthic diatoms suggest possible automatic classification schemes if adequate range information is available. Certainly, non-vegetative bottom features such as animals and man-made objects are sharply discernible when viewed at 685 nm, and path radiance due to backscattering does not reduce image contrast for fluorescence-dominated scenes.

TRANSITIONS

None as yet, these are relatively recent results which will be made available to other CoBOP investigators and the community at large.

RELATED PROJECTS

As part of the CoBOP program, this project is synergistic with numerous other CoBOP investigations. This project also provides data to and benefits from instrumentation developed under "Optical Variability and Bottom Classification in Turbid Water" (ONR CODE 3220M).

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